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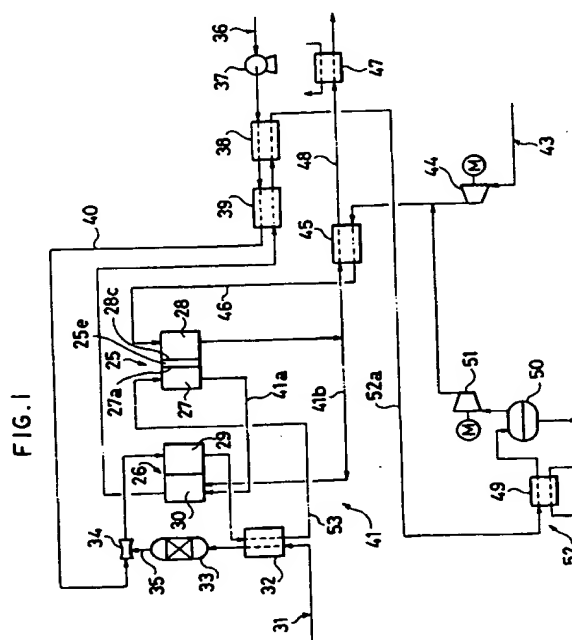
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**AT BE CH DE DK ES FR GB GR IT LI LU NL SE**(71) Applicant: **Ishikawajima-Harima Heavy Industries Co., Ltd.**  
**1-go, 2-ban, 2-chome, Ohtemachi Chiyoda-ku Tokyo(JP)**(72) Inventor: **Kobayashi, Kazunori****1202-103, Shiomi-dai, Isogo-ku  
Yokohama-shi, Kanagawa(JP)**Inventor: **Yoshida, Toshiaki**  
**1-34-2 Sakae-cho  
Tachikawa-shi, Tokyo(JP)**(74) Representative: **Schaumburg, Thoenes & Englaender**  
**Mauerkircherstrasse 31  
W-8000 München 80(DE)**(54) **Electric power producing system using molten carbonate type fuel cell.**

(57) An electric power producing system using a molten carbonate type fuel cell (25) comprises a fuel cell (25) whose anode chamber (27) is fed with hydrogen gas and whose cathode chamber (28) is fed with air (43) and carbon dioxide and a reformer (26) including a reforming chamber (29) for reforming fuel gas (31) into anode gas and a combustion chamber (30) for maintaining the reforming chamber temperature. In the reformer (26) fuel gas (31) and steam (36) are fed into the reforming chamber (29), the gases discharged from the anode chamber (27) are introduced into the combustion chamber (30) and non-reacted gases in the anode exhaust gas are burned with air (43), and heat produced by the combustion is utilized to heat the reforming chamber (29). Hydrogen-rich gas produced in the reforming chamber (29) is fed into the anode chamber (27), air (43) is introduced into the cathode chamber (28), the cathode exhaust gas is partially fed into the combustion chamber (30) whereas the remainder is discharged from the system (48), and the combustion gas from the combustion chamber (30) is separated from water and then recirculated into the cathode chamber (28). The anode exhaust gas and the cathode exhaust gas are directly introduced into the combustion chamber (30) so that the pressure in the anode and cathode chambers (27,28) is equalized.

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The present invention relates to an electric power producing system using molten carbonate type fuel cell, and particularly to such a system whose differential pressure between cathode and anode chambers is reduced.

Fuel cell produces electricity and water at the same time through a chemical reaction of hydrogen of fuel and oxygen of air, which reaction is a reversal reaction of electrolysis of water. Generally, a fuel cell comprises an electrolyte plate, an air electrode (cathode electrode) and a fuel electrode (anode electrode), and the electrolyte plate is sandwiched between these two electrodes. Fuel gas such as hydrogen is fed to the anode and the air containing carbon dioxide is fed to the cathode, the above-mentioned chemical reaction occurs to produce electric potential difference (or electric power) between the cathode and the anode. The power generation system also comprises a reformer which includes a reforming chamber and a combustion chamber. The fuel gas such as natural gas (NG) is reformed to a hydrogen-rich gas via the reformer. The fuel gas reacts with steam in the reforming chamber to be reformed to hydrogen gas and carbon monoxide gas. The reforming chamber is heated by heat from the combustion chamber in which fuel gas and air undergo combustion.

Referring to Figure 2 of the accompanying drawings, which illustrates a conventional power generation system using molten carbonate type fuel cells, numeral 1 denotes the fuel cell, 2 denotes the anode chamber, 3 denotes the cathode chamber, 4 denotes the reformer, 5 denotes the reforming chamber and 6 the combustion chamber.

The fuel gas 7 such as NG is preheated by a fuel preheater 8 and desulfurized by a desulfurizer 9. Then, the fuel gas 7 is led into an ejector 10 and then into the reforming chamber 5 of the reformer 4 with the steam 11. Water is changed into the steam 11 via an evaporator (preheater) 12 and a superheater 13 and introduced into the ejector 10. Then, the steam 11 reaches the reforming chamber 5 of the reformer 4 with the fuel gas 7, in which the fuel gas 7 and the steam 11 are reformed to hydrogen-rich gas, and then introduced into the anode chamber 2 of the fuel cell 1. Gases from the anode chamber 2 (called "anode exhaust gas") are about 700 degrees C ( $^{\circ}$ C) in temperature and contain non-reacted hydrogen. Therefore, the condensate is separated from the anode exhaust gas by a separator 18 via a first heat exchanger 14, a fuel preheater 8, a second heat exchanger 15, a heater 16 and a condenser 17. Then, the anode exhaust gas is fed into the combustion chamber 6 of the reformer 4, as fuel, via the second heat exchanger 15 and the first heat exchanger 17 by a blower 19. The temperature of the anode exhaust gas fed into the combustion chamber 6 is about

500 degrees C.

Air 20 is fed into an air preheater 22 by the blower 21 and preheated by part of the gases discharged from the cathode chamber 3. Then, part of the air 20 is fed into the cathode chamber 3 whereas the remainder is fed into the combustion chamber 6 of the reformer 4. Non-reacted hydrogen contained in the anode exhaust gas is combusted in the combustion chamber 6, and the combustion heat thereupon helps to maintain the reforming reaction of the fuel gas 7 with the steam 11 in the reforming chamber 5. Combustion fuel gas such as carbon dioxide is supplied to the cathode chamber 3.

Fuel used in the reformer 4 is the anode exhaust gas which is discharged from the anode chamber 2 and which contains hydrogen. The entire hydrogen is not consumed in the anode chamber 2. This fuel gas is condensed in the condenser 17 and separated from water in the separator 18 before reaching the combustion chamber 6 of the reformer 4. The air 20 which is preheated by the air preheater 22 and fed into the combustion chamber 6 is used for combustion of hydrogen contained in the anode exhaust gas. This combustion maintains the reaction temperature in the reforming chamber 5 of the reformer 4 at about 750 degrees C.

In the above-described conventional power generation system using fuel cell, however, the electrolyte migration and depletion may occur when the pressure difference between the anode and cathode chambers exceeds a certain value since the electrolyte of the fuel cell is molten carbonate. If the electrolyte depletion occurs, power generation is no longer expected. In order to overcome this problem or to maintain the pressure difference within an acceptable range, the pressure difference between anode gas and cathode gas has to be controlled. It is, however, difficult to control this pressure difference since the anode exhaust gas is introduced into the combustion chamber of the reformer via several devices such as a heat exchanger. The cathode exhaust gas is also discharged via devices such as a heat exchanger.

One object of the present invention is to provide a power generation system using molten carbonate type fuel cell whose pressure difference of the anode and cathode chambers is maintained within a suitable range without controlling the pressure difference of entrance and exit of the anode and cathode chambers.

Another object of the present invention is to compensate the pressure of the anode and cathode chambers and to recover great amounts of discharged heat produced in the system.

According to one aspect of the present invention, there is provided an electric power producing

system with a molten carbonate type fuel cell, comprising:

a molten carbonate type fuel cell including an anode chamber and a cathode chamber, air and carbon dioxide being fed into the cathode chamber to cause power generation; and

a reformer including a reforming chamber for reforming fuel gas into anode gas and a combustion chamber for maintaining the reforming temperature of the reforming chamber, fuel gas and steam being fed into the reforming chamber to reform them into hydrogen-rich gas, the gases discharged from the anode chamber being introduced into the combustion chamber and non-reacted gases in the gases discharged from the anode chamber being burned with air, and heat produced by the combustion being utilized to heat the reforming chamber, characterized in that the fuel gas is fed into the reforming chamber of the reformer with steam, that hydrogen-rich gas produced in the reforming chamber is fed into the anode chamber of the molten carbonate type fuel cell, that air is introduced into the cathode chamber of the molten carbonate type fuel cell, that gases from the anode chamber are fed into the combustion chamber of the reformer, that part of the gases from the cathode chamber is fed into the combustion chamber whereas the remainder is discharged from the system, and that gases from the combustion chamber are separated from water and then recirculated into the cathode chamber.

According to another aspect of the present invention, there is provided an electric power producing system with a molten carbonate type fuel cell, comprising:

a molten carbonate type fuel cell including an electrolyte, an anode and a cathode, the electrolyte being sandwiched by the anode and cathode, the anode being provided with an anode chamber through which hydrogen gas is fed to the anode and the cathode being provided with a cathode chamber through which air and carbon dioxide are fed to the cathode; and

a reformer including a reforming chamber for reforming fuel gas with steam into anode gas and a combustion chamber for maintaining the reforming temperature of the reforming chamber,

characterized in that the system further comprises:

a fuel feed line for feeding the fuel gas into the reforming chamber of the reformer;

a steam feed line for feeding the steam into the fuel feed line;

an anode gas feed line for feeding the anode gas produced in the reforming chamber into the anode chamber;

a cathode gas feed line for feeding cathode gas into the cathode chamber;

air feed means for introducing air into the cathode gas feed line;

an anode exhaust gas line connecting the anode chamber with the combustion chamber for introducing the gases discharged from the anode chamber into the combustion chamber;

a cathode exhaust gas line connecting the cathode chamber with the combustion chamber for feeding the gases discharged from the cathode chamber into the combustion chamber;

a cathode exhaust gas discharge line branched from the cathode exhaust gas line for discharging part of the gases discharged from the cathode chamber out of the system; and

a recycle line connecting the combustion chamber with the cathode gas feed line for recirculating gases discharged from the combustion chamber into the cathode gas feed line.

In the power generation system of the present invention, gases from the anode chamber (anode exhaust gas) and gases from the cathode chamber (cathode exhaust gas) are respectively and directly introduced into the combustion chamber so that the anode and cathode chambers are made equal in pressure, i.e., the pressure in two chambers is compensated. Gases discharged from the combustion chamber (combustion gas), too, are separated from water and heat-recovered, and then recirculated as cathode gas so that exhaust heat is effectively recovered.

Figure 1 is a block diagram showing one embodiment of the electric power-producing molten carbonate type fuel cell system of the present invention; and

Figure 2 is a block diagram showing a prior art power generation system using molten carbonate type fuel cell.

Now, a preferred embodiment of the present invention will be explained with reference to Figure 1.

In Figure 1, a fuel cell 25 and a reformer 26 are identical with those illustrated in Figure 2 and described in the "Background Art" of this specification. The fuel cell 25 includes an electrolyte 25e, a porous anode 27a and a porous cathode 28c. The anode 27a and cathode 28c sandwich the electrolyte 25e at respectively one face thereof, and the anode 27a is provided with an anode chamber 27 at the other face thereof, and the cathode 28c is provided with a cathode chamber at the other face thereof. The reformer 26 includes a reforming chamber 29 and a combustion chamber 30. Reforming catalyst is provided in the reforming chamber 29, and combustion catalyst is provided in the combustion chamber 30.

Fuel gas 31 such as NG is fed through a fuel gas feed line 35 into the reforming chamber 29 of

the reformer 26 via a fuel gas preheater 32, a desulfurizer 33 and an ejector 34. Water 36 is fed through a steam feed line 40 to be vaporized by an evaporator 38 and a superheater 39, and then fed into the reforming chamber 29 of the reformer 26 via an ejector 34.

Hydrogen-rich gases discharged from the reforming chamber 29 of the reformer 26 are supplied to the anode chamber 27 of the fuel cell 25 via the fuel gas preheater 32. Gases discharged from the anode 27 (anode exhaust gas) are introduced into the combustion chamber 30 of the reformer 26 through an anode exhaust gas line 41a which is one of the pressure compensating line 41.

Air 43 is fed into the cathode chamber 28 via an air preheater 45 by a blower 44 through a cathode gas feed line 46. Part of the gases discharged from the cathode 28 (cathode exhaust gas) is led into the combustion chamber 30 of the reformer 26 through the other line 41b of the pressure compensating line 41. Other exhaust gases are expelled through an exhaust gas line 48 via the air preheater 45 and a heat exchanger 48.

Gases burned in the combustion chamber 30 of the reformer 26 are recirculated through a combustion exhaust gas line 52a to the cathode gas feed line 46 upstream of the air preheater 45 via the superheater 39 and evaporator 38, a condenser 49 and a separator 50 by the blower 51. The combustion exhaust gas line 52a is a main line of the recirculation line 52.

Water 36 is forced into the evaporator 38 and preheater 39 by a pump 37, combustion exhaust gas from the combustion chamber 30 of the reformer 26 is also forced therein, so that the water 36 is vaporized to steam. The fuel gas 31 such as NG is in turn preheated by the fuel gas preheater 32, desulfurized by the desulfurizer 33, led into the ejector 34 and introduced into the reforming chamber 29 of the reformer 26 with the steam.

In the reforming chamber 29, the fuel gas 31 and the steam 36 are reformed to hydrogen-rich gas and carbon monoxide, and then preheated by the preheater 32 before being led into the anode chamber 27 of the fuel cell 25. The anode exhaust gas discharged from the anode chamber 27 which contains non-reacted hydrogen gas is directly introduced into the combustion chamber 30 of the reformer 26 via the anode exhaust gas line 41a with a high temperature (about 700 degrees C) being maintained.

Meantime, air 43 is forced into the air preheater by the air blower 44 and preheated by part of the cathode exhaust gas from the cathode chamber 28 of the fuel cell 25 before being fed to the cathode. Part of the cathode exhaust gas from the cathode 28 having a high temperature (about 700 degrees C) is fed to the combustion chamber

30 of the reformer 26 via the cathode exhaust gas line 41b. In this manner, exhaust gases from the anode chamber 27 and cathode chamber 30 are directly led into the combustion chamber 30 of the reformer 26 respectively. Therefore, the anode exhaust gas and cathode exhaust gas compensate the pressure of the counterpart of each other via the combustion chamber 30. As a result, the electrode pressure difference between the anode chamber 27 and cathode chamber 28 becomes substantially zero.

Hydrogen gas contained in the anode exhaust gas is burned in the combustion chamber 30, and the combustion heat maintains the temperature of the reforming chamber 29 at a predetermined value (about 750 degrees C) so that the fuel gas 31 and steam 36 flowing through the reforming chamber 29 undergo the reforming reaction.

Combustion exhaust gases such as carbon dioxide are condensed by the condenser 49 via the superheater 39 and the evaporator 38 on the steam line 40, and then condensed water is separated by the separator 50. After that, said gases are returned to the cathode 28c via the cathode feed line 46 by the blower 51. Then, reaction between hydrogen and oxygen occurs in the fuel cell 25 via the electrolyte 25e in order to produce electric power.

Gases from the anode chamber 27 and cathode chamber 28 are directly introduced into the combustion chamber 30 of the reformer 26 via the pressure compensating line 41, i.e., the combustion chamber 30 is connected to the anode chamber 27 and the cathode chamber 28. Therefore, the combustion chamber 30 compensates the pressure of the anode chamber 27 and cathode chamber 28 without controlling electrode pressure difference at the entrances and exits of the anode and cathode chambers 27 and 28. In other words, the pressure difference between the anode and cathode can be maintained within a certain adequately small range.

In addition, the anode exhaust gas which contains non-reacted hydrogen is used as fuel to the combustion chamber 30 and said gas is directly fed into the combustion chamber 30. Therefore, the difference between the anode exhaust gas temperature (about 700 degrees C) and the reforming reaction temperature (about 750 degrees C) of the reforming chamber 29 is small, and the anode exhaust gas is burned by the high temperature cathode exhaust gas (about 700 degrees C). Thus, a large amount of non-reacted hydrogen is not necessary to maintain the temperature of the reforming chamber 29. In comparison with the prior art system, the required amount of non-reacted hydrogen is made smaller, which results in higher fuel utilization efficiency and higher power generation efficiency.

Furthermore, the combustion gas from the com-

bustion chamber 30, which contains carbon dioxide and other gases, is a high temperature gas which contains not only the steam produced in the anode 27a but also the steam produced upon combustion of the non-reacted hydrogen contained in the anode exhaust gas. Hence, a large amount of heat is recovered from the exhaust gases when the water is condensed and separated therefrom.

#### Claims

1. An electric power producing system using a molten carbonate type fuel cell (25), comprising;
  - a molten carbonate type fuel cell (25) including an anode chamber (27) and a cathode chamber (28), air and carbon dioxide being fed into the cathode chamber (28) to cause power generation; and
  - a reformer (26) including a reforming chamber (29) for reforming fuel gas (31) into anode gas and a combustion chamber (30) for maintaining the reforming temperature of the reforming chamber (29), fuel gas (31) and steam (36) being fed into the reforming chamber (29) to reform them into hydrogen-rich gas, the gases discharged from the anode chamber (27) being introduced into the combustion chamber (30) and non-reacted gases in the gases discharged from the anode chamber (27) being burned with air (43), and heat produced by the combustion being utilized to heat the reforming chamber (29),
  - characterized in that the fuel gas (31) is fed into the reforming chamber (29) of the reformer (26) with steam (36), that hydrogen-rich gas produced in the reforming chamber (29) is fed into the anode chamber (27) of the molten carbonate type fuel cell (25), that air (43) is introduced into the cathode chamber (28) of the molten carbonate type fuel cell (25), that gases from the anode chamber (27) are fed into the combustion chamber (30) of the reformer (26), that part of the gases from the cathode chamber (28) is fed into the combustion chamber (30) whereas the remainder is discharged from the system (48), and that gases from the combustion chamber (30) are separated from water and then recirculated into the cathode chamber (28).
2. The electric power producing system of claim 1, wherein the fuel gas (31) is preheated by the hydrogen-rich gas, sulfurized and then fed into the reforming chamber (29) with the steam (36).
3. The electric power producing system of claim 1 or 2, wherein water is heated to steam (36) by the gases discharged from the combustion chamber (30), and then fed into the reforming chamber (29).
4. The electric power producing system of claim 3, wherein the gases discharged from the combustion chamber (30), after heating the water, are cooled so that water contained therein is condensed, and are recirculated with air (43) to the cathode chamber (28) after separation from the water.
5. The electric power producing system of claim 4, wherein the air (43) and the recirculated gases are preheated by the gases discharged from the cathode chamber (28) to the outside of the system (48) and then recirculated to the cathode chamber (28).
6. The electric power producing system of any one of the foregoing claims, wherein the gases discharged from the anode chamber (27) contain non-reacted hydrogen which is burned in the combustion chamber (30) with air contained in the gases discharged from the cathode chamber (28), and the combustion in the combustion chamber (30) heats the reforming chamber (29) to maintain the temperature of the reforming reaction in the reforming chamber (29).
7. The electric power producing system of any one of the foregoing claims, wherein gas pressure in the anode chamber (27) and gas pressure in the cathode chamber (28) are equalized by directly feeding into the combustion chamber (30) the gases discharged from the anode chamber (27) and the gases discharged from the cathode chamber (28) so that a pressure difference between the anode chamber (27) and the cathode chamber (28) is compensated.
8. An electric power producing system using a molten carbonate type fuel cell (25), comprising;
  - a molten carbonate type fuel cell (25) including an electrolyte (25e), an anode (27a) and a cathode (28c), the electrolyte (25e) being sandwiched by the anode (27a) and cathode (28c), the anode (27a) being provided with an anode chamber (27) through which hydrogen gas is fed to the anode (27a) and the cathode (28c) being provided with a cathode chamber through which air (43) and carbon dioxide are fed to the cathode (28c); and
  - a reformer (26) including a reforming chamber

(29) for reforming fuel gas (31) with steam (36) into anode gas and a combustion chamber (30) for maintaining the reforming temperature of the reforming chamber (29),

**characterized** in that the system further comprises:

a fuel feed line (35) for feeding the fuel gas (31) into the reforming chamber (29) of the reformer (26);

a steam feed line (40) for feeding the steam (36) into the fuel feed line (35);

an anode gas feed line (53) for feeding the anode gas produced in the reforming chamber (29) into the anode chamber (27);

a cathode gas feed line (46) for feeding cathode gas into the cathode chamber (28);

air feed means (44) for introducing air (43) into the cathode gas feed line (46);

an anode exhaust gas line (41a) connecting the anode chamber (27) with the combustion chamber (30) for introducing the gases discharged from the anode chamber (27) into the combustion chamber (30);

a cathode exhaust gas line (41b) connecting the cathode chamber (28) with the combustion chamber (30) for feeding the gases discharged from the cathode chamber (28) into the combustion chamber (30);

a cathode exhaust gas discharge line (48) branched from the cathode exhaust gas line (41b) for discharging part of the gases discharged from the cathode chamber (28) out of the system (48); and

a recycle line (52, 52a) connecting the combustion chamber (30) with the cathode gas feed line (46) for recirculating gases discharged from the combustion chamber (30) into the cathode gas feed line (46).

9. The electric power producing system of claim 8, wherein a preheater (32) is connected to the fuel feed line (35) and to the anode gas feed line (53) for heat exchanging the fuel gas and the reformed gas.

10. The electric power producing system of claim 9, wherein a desulfurizer (33) is connected to the fuel feed line (35).

11. The electric power producing system of claim 8 or 9, wherein the steam feed line (40) is connected to a water feed line (36), and a heat exchanger (38,39) through which the gases discharged from the combustion chamber (30) for recirculation flow is connected to the water feed line (36) so that water supplied through the water feed line (36) is vaporized.

12. The electric power producing system of claim 8, 9 or 10, wherein an ejector (34) is connected to the fuel feed line (35) and to the steam feed line (40) so that the fuel gas (31) is mixed with the steam in the ejector (34) and fed to the reformer (26).

13. The electric power producing system of any one of claims 8 to 12, wherein the anode exhaust gas line (41a) communicates with the cathode exhaust gas line (41b) via the combustion chamber (30) so that a pressure difference between the anode chamber (27) and the cathode chamber (28) is compensated.

14. The electric power producing system of any one of claims 8 to 13, wherein the recycle line (52, 52a) includes a cooling device (38,39,49) for condensing the steam (36) contained in the gases discharged from the combustion chamber (30) and further includes a gas-liquid separating device (50) for separating the condensed water from the gases.

15. The electric power producing system of claim 14, wherein the cooling device (38,39,49) includes a heat exchanger (38,39) for vaporizing the water supplied.

16. The electric power producing system of claim 14 or 15, wherein the gases whose moisture has been removed by the gas-liquid separating device (50) are recirculated by a blower (51) into the cathode gas feed line (46).





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## EUROPEAN SEARCH REPORT

Application Number

EP 90 10 9042

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	PATENT ABSTRACTS OF JAPAN, vol. 13, no. 374 (E-808)[3722], 18th August 1989; & JP-A-1 128 364 (ISHIKAWAJIMA HARIMA HEAVY IND. CO.) 22-05-1989 * Abstract *	1-11, 13-16	H 01 M 8/06
Y	IDEM	12	
Y	US-A-3 585 077 (E.I. WALDMAN) * Figure 1; claim 1 *	12	
X	PATENT ABSTRACTS OF JAPAN, vol. 12, no. 379 (E-667)[3226], 11th October 1988; & JP-A-63 126 173 (JAPAN FUEL TECHNOL. CORP.) 30-05-1988 * Abstract *	8	
A	PATENT ABSTRACTS OF JAPAN, vol. 8, no. 111 (E-246)[1548], 24th May 1984; & JP-A-59 27 469 (TOKYO DENRYOKU K.K.) 13-02-1984 * Abstract *	7	
A	PATENT ABSTRACTS OF JAPAN, vol. 13, no. 346 (E-798)[3694], 3rd August 1989; & JP-A-1 105 475 (ISHIKAWAJIMA HARIMA HEAVY IND., CO.) 21-04-1989 * Abstract *	1	TECHNICAL FIELDS SEARCHED (Int. Cl.5)  H 01 M
A	US-A-4 128 700 (UNITED TECHNOLOGIES CORP.) * Column 3, lines 21-22; claims 1,4,9 *	1	
The present search report has been drawn up for all claims			
Place of search  The Hague		Date of completion of search  14 January 91	Examiner  D'HONDT J.W.
<b>CATEGORY OF CITED DOCUMENTS</b> X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention  E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons  & : member of the same patent family, corresponding document			

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FIG. 2

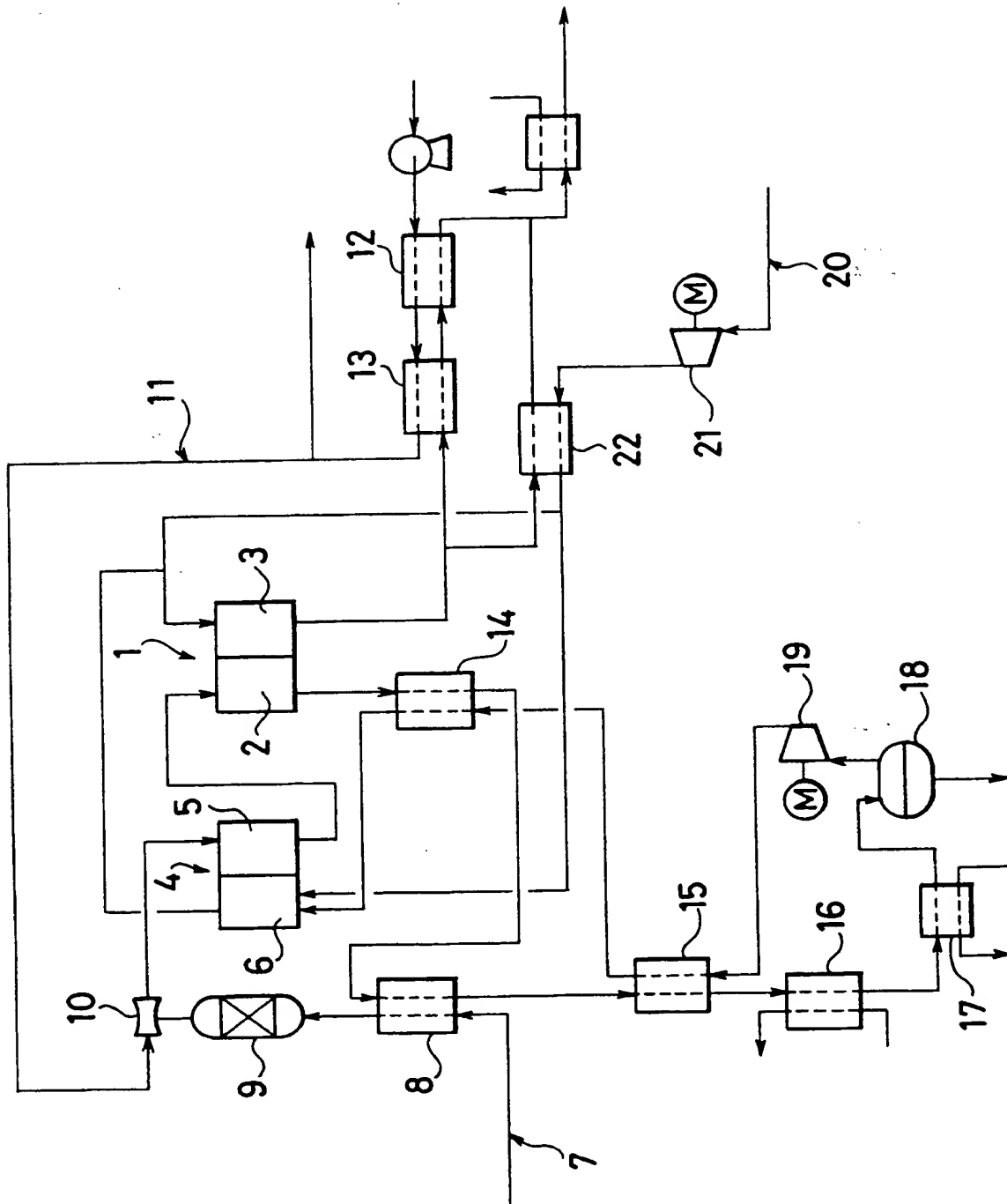


FIG. 1

